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Sub-Thermocline Maximums of the Dinoflagellates *Gymnodinium simplex* (Lohmann) Kofoid and Swezy and *Gonyaulax polygramma* Stein

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Short Papers and Notes:

SUB-THERMOCLINE MAXIMUMS OF THE DINOFLAGELLATES *Gymnodinium simplex* (LOHMANN) KOFOID AND SWEZY AND *Gonyaulax polygramma* STEIN

Sournia (1974) reviewed the literature on the diurnal vertical migration of dinoflagellates. Eppley *et al.* (1968), Walsh *et al.* (1974) and Kiefer and Lasker (1975) observed a migration pattern that showed an ascent of marine dinoflagellates to the surface during the morning and a descent during the evening. Kiefer and Lasker (1975) documented an altered phase relationship with daylight.

Kamykowski and Zentara (1977) reviewed observations of the diurnal vertical migration of dinoflagellates in thermally stratified water columns. Most marine field observations were made either in isothermal or weakly stratified (< 2° C) systems. The present paper reports on the behavior of two marine dinoflagellates, *Gonyaulax polygramma* Stein and *Gymnodinium simplex* (Lohmann) Kofoid and Swezy as described in Wood (1968), in a water column having both a well-developed thermocline and a weak halocline.

METHODS

An offshore tower, STAGE I (30° 00′N, 85° 54′W), is maintained by the U.S. Naval Coastal Systems Laboratory, Panama City, Florida. STAGE I, located at a water depth near 32 m about 22.2 km offshore, served as a platform from which samples were taken every 4 hours for the 24 hr period from 1900 hr on 10 May 1978 to 1900 hr on 11 May 1978. The sample regime began with a profile using a MARTEK TCD provided with sufficient cable to reach 23 m depth. A high volume pump system (failed after the first profile) verified that the temperature at 32 m was similar to that at 23 m. During daylight hours, a Secchi depth determination and a profile with a LAMBDA submarine photometer used with surface and subsurface quantum sensors were taken. A low volume pump was raised through the water column twice: the first profile provided water for a flow-through TURNER DESIGNS fluorometer; the second profile collected discrete samples at water depths of 0,8,16,24, and 32 m. Aliquots were used for determinations of salinity, nitrate, chlorophyll *a* and phytoplankton species counts. Salinity was measured on a salinometer; nitrate-nitrogen and *in vitro* chlorophyll *a* (fluorometry) were determined according to the methods in Strickland and Parsons (1968). Phytoplankton species counts were determined on an inverted microscope according to the procedure of Utermohl (1931). The chlorophyll *a* determinations were used to calibrate the *in vivo* fluorescence profiles.

Supporting data were obtained from the STAGE I instrumentation for wind speed and direction and for swell height (Bruce Lloyd, personal communication). U.S. Dept. of Commerce Tide Tables (USDC, 1978) provided tide estimates and sun cycle.

RESULTS

The general physical oceanography of the area surrounding STAGE I was discussed by Tolbert and Austin (1959), Boston (1964) and Dowling (1966). Table 1 summarizes the characteristics of the physical environment during the sample interval. The tide exhibited a diurnal period characteristic of the area; a high occurred at 1206 hr on 11 May and lows occurred at 2235 hr on 10 May and at 2319 hr on 11 May. The sun set at 1843 hr and rose at 0510 hr; the light:dark cycle was 13.33 hr:10.67 hr. Skies were generally clear in the morning, but clouded over in the afternoon. Wind speed and direction were variable attaining maximum speeds from SSE in late afternoon. Wave height ranged between 0.34-0.49 m and varied closely with the wind speed. Internal waves, if present, were of short period and low amplitude as shown by the stability of the 19° C isotherm. The upper water column was generally clear as shown by an average Secchi depth of 16 m.

Table 2 summarizes the general physical and chemical characteristics of the water column. As suggested by the Secchi depth, the photic zone extended to the bottom of the water column. The maximum temperature gradient reached 7 C°; mid-thermocline occurred near 16 m. The maximum salinity gradient was about 2°/₀₀ and mid-halocline also occurred near 16 m. Nitrate ranged between 0.20-0.55 μg-at NO_3-N l^{-1} above the thermocline and between 0.67-4.83 μg-at NO_3-N l^{-1} below 24 m.

The distribution of phytoplankton species in the northeastern Gulf of Mexico was described by Balech (1967). Additional biological information was presented in SUSIO (1973). Fig. 1 summarizes the relationship between the chlorophyll *a* distribution and the temperature structure. Two biomass peaks were apparent in the 1900 hr profile on 10 May. The upper was located at 15 m (19° C); the lower was located at 23 m (17° C). At 2300 hr, a single biomass peak occurred at 22 m (17° C). At 0300 hr, two biomass peaks again occurred. The upper was at 22 m (17° C); the lower was a broad band centered at 29 m (17° C). Soon after sunrise (0700 hr), a uniform biomass band occurred below 23 m (17° C). At 1100 hr, a more discrete biomass peak was present at 25 m (17° C). This maximum rose to 23 m (17° C) by 1500 hr and to 21 m (17.1° C) by 1900 hr on 11 May.

The complex chlorophyll *a* patterns in Fig. 1 are clarified by Fig. 2. Two dinoflagellates were abundant below the thermocline. *Gonyaulax polygramma* exhibited concentrations up to 660 cells ml^{-1} and *Gymnodinium simplex* exhibited concentrations up to 1690 cells ml^{-1}. *G. polygramma* was concentrated at 16 m at 1900 hr (10 May), 32 m at 0300 hr, 32 m and 24 m at 0700 hr, and 24 m at 1500 hr and 1900 hr (11 May). *G. simplex* appeared primarily in the 24 m samples.

DISCUSSION

Sampling from a geographically fixed tower means that time-series data on plankton populations are subject to vagaries due to the currents. Generally, the surface currents at STAGE I are domi-

TABLE 1. The time course of sunlight, wind speed, wind direction, wave height, thermocline depth, and Secchi depth at STAGE I on 10-11 May 1978.

Date	Time[1] (hr)	Sunlight[2] (μein $m^{-2}sec^{-1}$)	Wind Speed Avg / Max (km hr^{-1})	Wind Direction[3] Avg / Max (deg)	Wave Height (m)	19° Depth (m)	Secchi Depth (m)
5/10	1900	—	20.2/31.7	271.2/277.5	0.39	15.0	—
	2300	—	—	—	—	14.5	—
5/11	0300	—	—	—	—	14.5	—
	0700	500	12.8/24.3	53.3/ 57.5	0.34	15.0	14
	1100	1600	19.1/30.6	89.4/ 92.5	0.39	15.5	19
	1500	—	29.1/41.7	161.7/172.5	0.49	16.5	15
	1900	—	21.3/32.6	152.6/162.5	0.41	15.0	—

[1]Tides at Panama City, Florida
5/10 1130:0.43m, 2235:-0.03m
5/11 1206:0.40m, 2319:-0.00m
[2]Sunrise 0510; Sunset 1843
[3]Wind direction increases clockwise from true north

TABLE 2. The range of light intensity, temperature, salinity and nitrate measured at 8 meter intervals between the surface and the bottom at STAGE I during 10-11 May 1978.

Depth (m)	Light Intensity (% surface)	Temperature (°C)	Salinity (‰)	Nitrate (μg-at NO_3-N l^{-1})
0	100	22.0-24.0	33.74-33.78	0.30-0.39
8	15-30	21.2-22.0	33.73-33.76	0.23-0.53
16	4-13	17.2-20.8	34.25-35.26	0.21-0.23
24	3-8	17.0	35.54-35.60	0.67-2.56
32	1-7	~17.0	35.64-35.80	2.82-4.83

nated by wind and tide (Boston, 1964). The historical maximum wind-driven surface speeds are just under 3.7 km hr-1. Under stratified conditions, wind-driven bottom currents are 60-75% of the surface currents. Bottom flow is dominated by tidal currents; these can exceed 1.85 km hr-1. Net movement of water at STAGE I is to the southeast. In the present case, the net transport is assumed much less than the maximum due to the variable winds and cyclic character of the tidal currents. Also, the organisms under consideration are primarily associated with the bottom layer.

The chlorophyll *a* data in Fig. 1 and the species counts in Fig. 2 suggest that *G. polygramma* underwent a sub-thermocline diurnal vertical migration between 15 m (19°C) and 32 m (17°C) and that *G. simplex* remained relatively stationary near 24 m (≈17°C). The large variation in *G. simplex* cell numbers observed at 24 m may result from the inaccuracies of sample bottle placement or from a low amplitude (few meters) diurnal vertical migration. In some of the profiles (*i.e.* 2300 hr) the actively migrating species was moving through the depth of the relatively stationary species. *G. polygramma* experienced higher light intensities than *G. simplex;* the latter species remained near the top of the nutrient gradient throughout the sample period. *G. polygramma* moved in the water column with the classical phase relationship with respect to daylight. Though the sample spacings were too large for precise determinations, the descent appeared to begin after sunset (1943 hr) and the ascent appeared to begin near sunrise (0510 hr). The descent speed was 1.75 m hr-1; this rate is well within the range recorded for other dinoflagellates (Kiefer and Lasker, 1975).

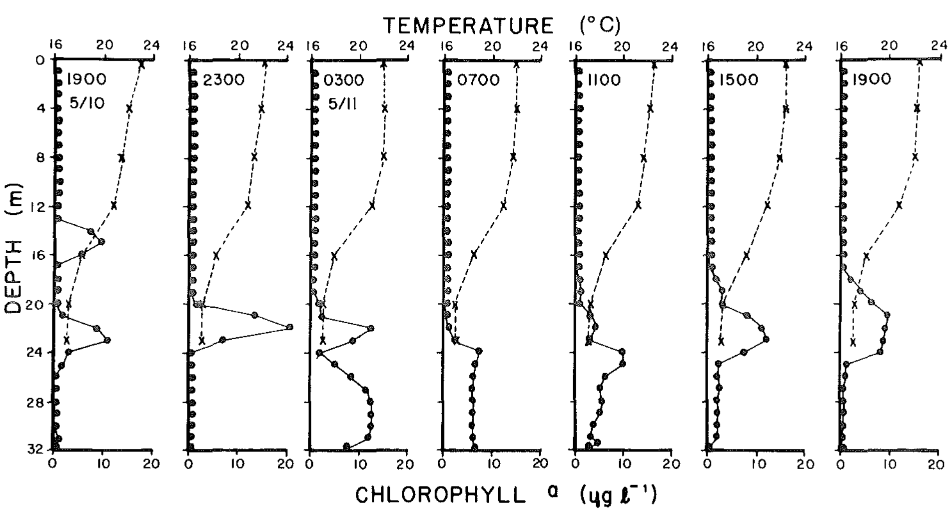

Figure 1. Profiles of temperature (broken line) and chlorophyll *a* (solid line) collected at 4 hour intervals on 10-11 May 1978 from STAGE I located in 32 m water depth.

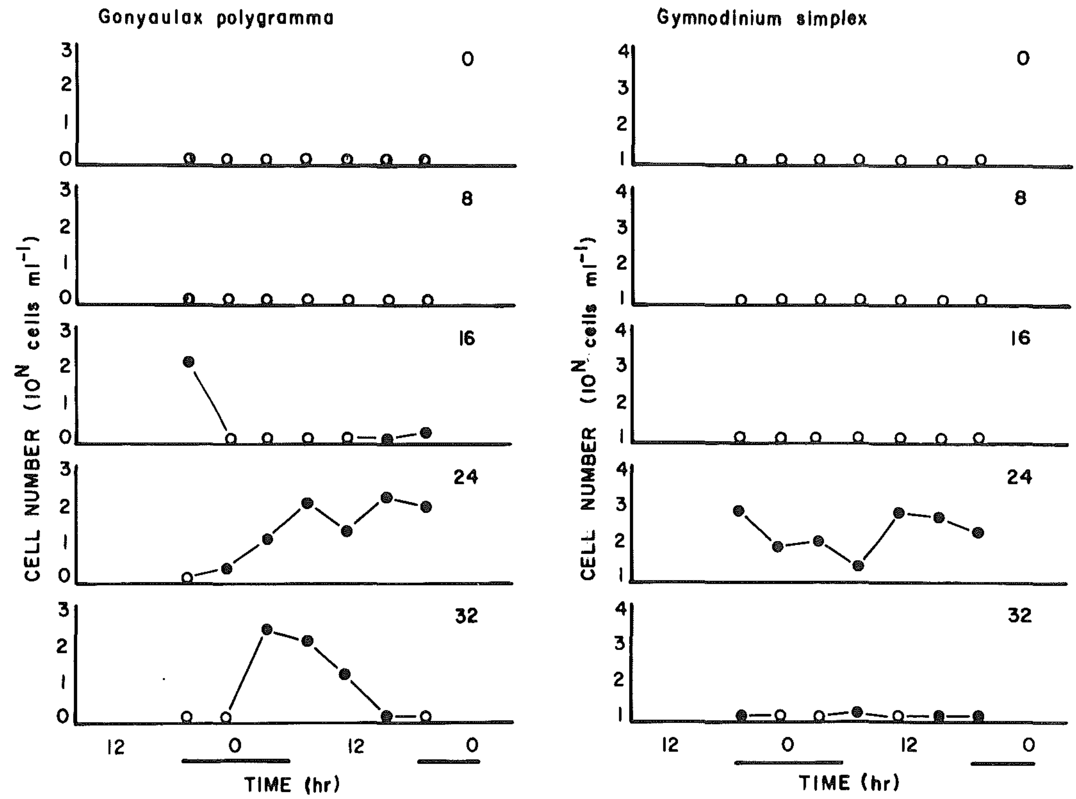

Figure 2. Cell numbers (log axis) of *Gonyaulax polygramma* and *Gymnodinium simplex* determined from samples collected at 0, 8, 16, 24, and 32 m depth at 4 hr intervals on 10-11 May 1978. Open circles represent samples in which no cells were observed; solid circles represent samples in which cells were observed. Solid lines below the time axis distinguish night.

G. polygramma did not appear as high in the water column in the last profile as it did in the first. This may be related to the increased wind speeds on the afternoon of 11 May. The cells may have avoided the more turbulent upper layer by remaining deeper in the water column. Alternatively, those cells that ventured higher in the water column may have been mixed into the upper layer during thermocline erosion.

Steidinger (1975) hypothesized that benthic cysts may influence the appearance of some dinoflagellates off the Florida coast. She presented evidence that red tides begin offshore and move onshore if physical conditions are appropriate. One interpretation of the observations in the present paper is as an intermediate stage between benthic cysts and red tides. A possible time sequence begins with growth conditions in the lower layer of the water column that activate benthic cysts of selected dinoflagellates. These cells assume behavioral patterns that optimize growth for the species under the encountered conditions. Cell division continues until substantial populations (10^2 cells ml^{-1}) occur over a large area. Changes either in species behavior or in the physical environment may then expose these dispersed populations to the convergence mechanisms described in Wyatt (1975).

CONCLUSIONS

1) A sub-thermocline, sub-halocline bloom of two dinoflagellates, *Gonyaulax polygramma* and *Gymnodinium simplex*,

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was observed 22.2 km off Panama City, Florida.

2) *G. polygramma* underwent a diurnal vertical migration between 15 m (19° C) and 32 m (17° C) depth. It migrated with a classical phase relationship with respect to daylight; descent speeds averaged 1.75 m hr^{-1}.

3) Maximum cell concentrations were: *G. polygramma* = 660 cells ml^{-1} and *G. simplex* = 1690 cells ml^{-1}.

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LITERATURE CITED

Balech, E. 1967. Dinoflagellates and tintinnids in the Northeastern Gulf of Mexico. Bulletin of Marine Science *17*, 280-298.

Boston, N.E.J. 1964. Observations of tidal period internal waves over a three day period off Panama City, Florida. Texas A&M Ref. 64-20 T. 49 pp.

Dowling, G.B. 1966. Low frequency shallow water internal waves at Panama City, Florida. U.S. Navy Mine Defense Lab, Panama City, Florida, Research Report 313. 59 pp.

Eppley, R. W., O. Holm-Hansen, and J.D.H. Strickland. 1968. Some observations on the vertical migration of dinoflagellates. Journal of Phycology *4*, 333-340.

Kamykowski, D. and S. J. Zentara. 1977. The diurnal vertical migration of motile phytoplankton through temperature gradients. Limnology and Oceanography *22*, 148-151.

Kiefer, D.A. and R. Lasker, 1975. Two blooms of *Gymnodinium splendens* Lebour; an unarmoured dinoflagellate. Fishery Bulletin, U.S. *73*, 675-678.

Sournia, A. 1974. Circadian periodicities in natural populations of marine phytoplankton. Advances in Marine Biology *12;* 325-389.

Steidinger, K.A. 1975. Basic factors influencing red tides. p. 153-162. *In:* Toxic dinoflagellate blooms. Proc. Inter. Conf. First Mass. Sci. Tech. Found.

Strickland, J.D.H. and T.R. Parsons. 1968. A practical handbook of seawater analysis. Fisheries Research Board of Canada. Bulletin *167*, 1-311.

SUSIO-State University System of Florida Institute of Oceanography 1973. A summary of knowledge of the Eastern Gulf of Mexico. unpaginated.

Tolbert, W.H. and G.B. Austin. 1959. On the nearshore marine environment of the Gulf of Mexico at Panama City, Florida. U. S. Navy Mine Defense Lab, Panama City, Florida Technical Paper TP161. 104 pp.

U.S.D.C.-U.S. Department of Commerce 1978. NOAA, NDS Tide Tables, East coast of North and South America including Greenland.

Utermohl, H. 1931. Neue wege in der quantitativen erfassung des planktons. Internationale Vereinigung fur Theoretische and angewundle Limnologie Verhandlungen *5*, 567-597.

Walsh, J. J., J. C. Kelley, T. E. Whitledge, J. J. MacIsaac and S. A. Huntsman. 1974. Spin-up of the Baja California upwelling ecosystem. Limnology and Oceanography *19*, 553-572.

Wood, E.J.F. 1968. Dinoflagellates of the Caribbean Sea and Adjacent Seas. Univ. of Miami Press Coral Gables. 143 pp.

Wyatt, T. 1975. The limitations of physical models for red tides. *In:* LoCicero, V.R.(ed) Proceedings of The First International Conference on Toxic Dinoflagellate Blooms. Massachusetts Science and Technology Foundation, Wakefield, Massachusetts. p. 81-93.

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